Modeling the Time-Dependent Optical Properties of the Multicomponent Aerosols in the Marine Boundary Layer

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LONG-TERM GOALS

The ultimate goal of this project is to improve the predictive understanding of the time-dependent, frequency-dependent, radiative properties of multicomponent aerosols containing mineral dust in the marine environment.

OBJECTIVES

Specific objectives of our research are:

(1) elucidate the links between dust particles morphology (shape and size), composition, optical properties and related radiative effects;

(2) relate the properties of dust to its source and investigate the evolution of dust properties during transport in the marine boundary layer, focusing on the comparative analysis of the Asian, African, Southwestern U.S., and Saudi Arabian types of dust.

(3) improve algorithms for prediction of frequency-dependent optical properties of mineral dust accounting for its mineralogical composition, life cycle, and interaction with other atmospheric aerosols in the clean and polluted marine environment.

APPROACH

Our approach combines an integrated analysis of the empirical data on dust microphysical, optical, and radiative properties and advanced numerical modeling techniques. During FY2002, we were focusing on the analysis of data acquired during the ACE-Asia field experiment conducted in Spring of 2001.

WORK COMPLETED

We performed an integrated analysis of the aerosol time-of-flight mass spectroscopy data provided by Prof. Prather's group (Univ. of California) and electronic microscopy data provided by Dr. Anderson (Univ. of Arizona) to identify the composition and morphology of multicomponent aerosol containing

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14. ABSTRACT
The ultimate goal of this project is to improve the predictive understanding of the time-dependent, frequency-dependent, radiative properties of multicomponent aerosols containing mineral dust in the marine environment.

15. SUBJECT TERMS

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mineral dust (MCA-D) as a function of size in the clean and polluted marine conditions under varying dust loadings during the ACE-Asia field experiment (Sokolik et al., 2002b).

Based on a new technique developed in FY 2001, we developed new dust optical models for the Saharan dust analog and Asian dust analog for remote sensing at solar wavelengths (Kalashnikova and Sokolik 2002 a,b,c). These models are currently tested in the MISR aerosol retrieval algorithms. In addition, new dust models were used in conjunction with lidar data collected in Spring of 2001 over Japan to identify the effects of dust nonsphericity (Murayama et al., 2002).

Combining satellite observations (TOMS, SeaWiFS, and MODIS) and meteorological data provided by the weather stations in China and Mongolia, we characterized individual dust outbreaks and reconstruct the transport routes of dust plumes during March-April of 2001 (Darmenova and Sokolik, 2002). These data were incorporated into the Asian Dust Databank which we have been developing during the past several years (Xuan and Sokolik, 2002 a, b, c)

We estimated the effect of atmospheric mineral dust on the narrowband sensors (e.g., MODIS, AVHRR, GOES) operating in the IR spectral region (Sokolik, 2002 b,e). To compute IR radiances accounting for multiple scattering and absorption by aerosols and atmospheric gases, we employed a new radiative transfer code which combines the line-by-line algorithm and discrete ordinate technique. New dust optical models required for such computations were developed for the representative mineral mixtures.

Overall, we successfully completed all tasks planned for FY2002.

RESULTS

ACE-Asia data revealed that atmospheric mineral dust were often internally mixed (aggregated) with other chemical species. Since both climate studies (e.g., IPCC) and remote sensing retrievals treat atmospheric aerosols as an external mixture of distinct aerosol types (such as dust, sulfates, black carbon), it is important to determine the magnitude of radiative impacts of multicomponent aerosol containing mineral dust (MCA-D). Based on an integrated analysis of the aerosol time-of-flight mass spectroscopy data and electronic microscopy data collected during the ACE-Asia experiment, several representative MCA-D size distributions were reconstructed and then used in computations of optical characteristics (Sokolik et al., 2002b). These results present a first attempt to develop new optical models for internally mixed aerosol containing dust for remote sensing at solar wavelengths.

A better understanding of Asian dust sources and transport routes of dust outbreaks is critical to improving the prediction of various dust impacts over the East Asia- North Pacific region.
Merging satellite observations and meteorological data over China and Mongolia, we identified the active dust sources during the Spring of 2001, estimated the duration of individual dust outbreaks and reconstruct the transport routes of dust plumes on the case-by-case basis (Darmenova and Sokolik, 2002). We demonstrate that a combination of meteorological visibility data, TOMS Aerosol Index, MODIS optical depth over the land, and a qualitative analysis of MODIS, AVHRR, and SeaWiFS imagery enables to constrain the regions of origin of dust outbreaks, though various limitations of such an approach were revealed. Over the oceans, the presence of persistent clouds provides a main limitation in identifying the regions in the Pacific Ocean affected by dust outbreaks, so only partial reconstruction of dust transport routes reaching the west cost of the U.S. was possible.

Since IR remote sensing is extensively used for determining the key atmospheric and oceanic properties (such as the atmospheric temperature profile, water vapor, trace gases, and sea surface temperature, SST), it is critical to understand the extent to which the retrievals of these properties from satellite narrowband and high-resolution sensors can be affected by the presence of dust. To address this issue, we considered several realistic scenarios of loadings and compositional mixtures of atmospheric dust (Sokolik, 2002 b, e). We demonstrate that the presence of dust decreases the brightness temperature depending mainly on the dust loading, though the composition becomes important as the loading increases. The moderate dust loading can result in a decrease of brightness temperature by 5-10 K in the IR window over the oceans. Given the SST desirable accuracy of about 0.2 K, even the light dust loading can causes non negligible errors. Our analysis revealed that narrowband sensors (e.g., MODIS, AVHRR, GOES) have different sensitivity to dust composition depending on a particular channel. To illustrate, Figure 1 shows the effect of dust on the brightness temperature that would be observed by satellite narrowband sensors for representative dust mixtures for light and moderate loadings. We conclude that dust must be accounted for in atmospheric correction algorithms if the retrievals of the sea surface temperature and atmospheric gaseous species from the thermal IR radiances are to be of high accuracy.

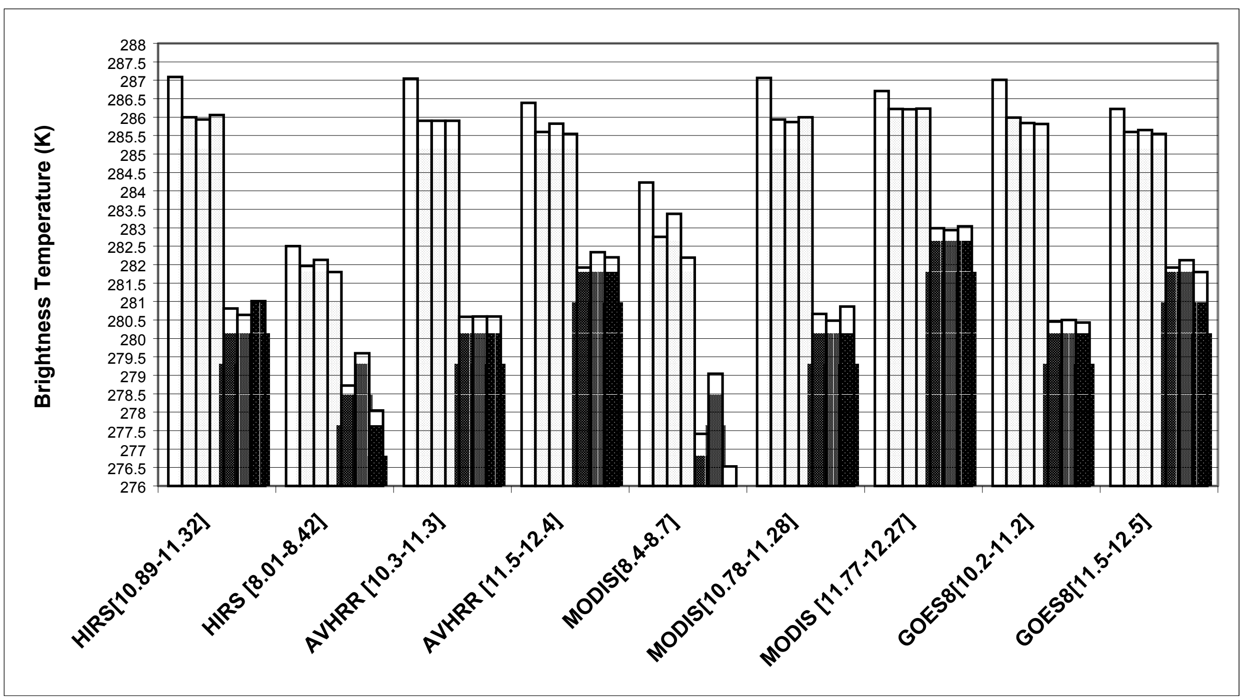

Figure 1. Brightness temperature that would be observed by the narrowband sensors for the clear sky (open columns), light dust loading (light color columns) and moderate dust loading (dark color columns). For each dust loadings, the first, second and third column correspond to different dust composition mixtures (Sokolik, 2002b).

IMPACT/APPLICATIONS

Our developed techniques to model the spectral optical properties of multicomponent aerosol containing dust can be employed in various remote sensing applications and in aerosol chemical transport models. Dust models are available at the dedicated web site: http://irina.colorado.edu/data-ref-dust.htm

TRANSITIONS

Our main results were published in peer-reviewed journals and presented at numerous scientific meetings.

RELATED PROJECTS

We are currently independently funded under the NSF Atmospheric Chemistry Program to work on the characterization of dust sources in China in the scope of the ACE-Asia Experiment. We also funded by MURI/University of Wisconsin to develop new dust models for hyperspectral remote sensing. Overall, our work on these projects will provide a better understanding of sources, transport and properties of Asian dust leading to more realistic treatments of dust in remote sensing applications and climate studies.

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